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TITLE OF PROPOSED PROJECT Collaborative Research: Aerosol Characterization Experiment (ACE) – Asia Surface Network Implementation, Operations, and Coordination						
REQUESTED AMOUNT		PROPOSED DURATION (1-60 MONTHS) 48 months		REQUESTED STARTING DATE 1 August 2000		SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
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A. PROJECT SUMMARY

The ACE-Asia Network, one of three components of the ACE-Asia Program, is being established to characterize the spatial and temporal (synoptic to interannual) variability of key aerosol chemical, physical and optical properties in near surface air over eastern Asia and the western Pacific. The Network at present is only loosely organized, and recognizing the benefits of coordinating the activities at the participating sites, the three PIs for this collaborative proposal have designed a series of steps to make the ACE-Asia Network a more focused program. The objectives for this proposal are as follows: (1) to develop the Network infrastructure; (2) to coordinate and standardize to the extent possible measurement activities for studies of aerosol composition and mass, aerosol optical properties and radiative fluxes, and wet deposition; (3) to intercompare analytical methods and instrumentation; (4) to provide training where desirable; (5) to assist in assuring and controlling data quality; (6) to develop a data archive; and (7) to develop resources for teaching, training, and learning with respect to radiative processes, atmospheric chemistry and global change.

Activities to be undertaken include the installation of a 20-m tall outrigger platform at Cheju; the preparation of standard operating procedures for collection, processing and analysis of aerosol and rainwater samples and for measurements of aerosol optical properties and radiative fluxes; the development of measures for standardizing and documenting quality assurance and quality control procedures; the construction of an ACE-Asia Network web page, the organization of an intercomparison workshop for aerosol optics and radiation instrumentation; and the preparation of web-based materials to be used for educational purposes. This last activity will have a direct impact on advancing knowledge of the atmospheric sciences because the data from the program will be used in courses at the University of Colorado on atmospheric chemistry, air pollution, solar and thermal radiation, and planetary atmospheres. The archive will be available to the modeling community; procedures for access to the data and authorship of resulting publications are detailed on the ACE-Asia web site. The data archive also will be made available to the modeling community following the ACE-Asia program guidelines for the use of data and co-authorship of scientific publication.

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C. PROJECT DESCRIPTION

1. RESULTS FROM PRIOR NSF SUPPORT

a. R. Arimoto

<u>TITLE:</u>	Biogeochemical Cycling of Atmospheric Trace Elements and Mineral Aerosol over Central and Eastern Asia
<u>NSF AWARD NUMBER:</u>	ATM 91-14072
<u>AMOUNT:</u>	\$307,733
<u>PERIODS OF SUPPORT:</u>	1 September 1991 to 31 August 1995

Although the PI has received more recent NSF support, this award is most closely related to the present proposal. For this project, aerosol particles collected through cooperative ground-based sampling programs in Asia were analyzed to (1) determine the natural and anthropogenic components of the airborne particulate material, (2) characterize the temporal variability in atmospheric dust concentrations, (3) investigate the meteorological conditions responsible for the changes in the dust concentrations, and (4) estimate the atmospheric deposition rates of mineral aerosol and selected trace elements to the waters bordering eastern Asia. Other initiatives focused on the atmospheric transport of soils in relation to past climatic changes, and one particularly noteworthy study involved a comparison of the elemental composition of contemporary aerosol particles and Chinese loess. Initial studies also were done to begin investigating the effects of Asian dust on the flux of solar radiation to the Earth's surface.

This award contributed to education and the development of human resources on several levels. First, the award supported the research of Dr. Yuan Gao who received her Ph. D. in 1994 from the University of Rhode Island (URI). The award also provided partial support for a year-long visit to URI (1992) by Dr. Xiaoye Zhang, from the Xi'an Laboratory of Loess and Quaternary Geology (XLLQG), PRC. Dr. Zhang's work was mainly supported by grants from the Natural Science Foundation of China, but some support was provided by this award. After returning to China, Dr. Zhang entered graduate school and was awarded his Ph. D. in 1995. Finally, the MS research of Ms. Zhihong Wang, Third Institute of Oceanography, State Oceanic Administration, Xiamen, PRC, was based on studies partially supported by this award.

Collaboration developed through this award has involved other Asian scientists, including Dr. Ming-yu Zhou, Mr. Liqi Chen, and Mr. Deyu Gu of the State Oceanic Administration, PRC and Dr. Dong Soo Lee of Yonsei University, Korea. Another important contribution to education and human resources was that the research supported by this award was the foundation for a two-day workshop on Asian dust held at URI in 1992, with additional support from, URI. The nineteen speakers at the workshop included geologists, oceanographers and atmospheric scientists from Japan and China and from six universities in the U.S. The meeting attracted sufficient attention to warrant a note in the Chinese scientific journal *Acta Meteorologica Sinica* (Gao, 1992).

Publications Resulting from ATM 91-14072:

- Arimoto, R., Y. Gao, M. Zhou, D. S. Lee, L. Chen, D. Gu, Z. Wang, Atmospheric Deposition of Trace Elements to the Western Pacific Basin, In: *Atmospheric Deposition of Contaminants to the Great Lakes and Coastal Waters*, edited by J. E. Baker, SETAC Press, Pensacola, FL, pp. 209-225, 1997.
- Gao, Y., Asian dust workshop held in U.S.A., *Acta Meteorol. Sinica*, 6, (in English) 1992.
- Gao, Y., R. Arimoto, R. Duce, L. Q. Chen, M. Y. Zhou, D. Y. Gu, Atmospheric non-sea-salt sulfate, nitrate and methanesulfonate over the China Sea, *Journal of Geophysical Research*, 101, 12,601-12,611, 1996.
- Gao, Y. R. Arimoto, R. A. Duce, X. Y. Zhang, G. Y. Zhang, Z. S. An, L. Q. Chen, M. Y. Zhou, and D. Y. Gu, Temporal and spatial distributions of mineral aerosol and its total deposition over continental China and the China Sea, *Tellus* 49B, 172-189, 1997.
- Gao, Y., R. Arimoto, M.Y. Zhou, J.T. Merrill, and R.A. Duce, Relationships between the dust concentrations over eastern Asia and the remote North Pacific, *Journal of Geophysical Research*, 97, pp. 9867-9872, 1992.
- Gao, Y., R. Arimoto, R.A. Duce, D.S. Lee, and M.Y. Zhou, Input of atmospheric trace elements and mineral matter to the Yellow Sea during the spring of a low dust year, *Journal of Geophysical Research*, 97, pp. 3767-3777, 1992.
- Chen, L.Q., P.F. Gao, Y.H. Zhang, Q. Yu, R. Arimoto, Y. Gao, and R.A. Duce, The atmospheric characteristics of marine aerosols over Xiamen, *Acta Oceanologica Sinica*, 15, 23-32, 1993.
- Zhang, X., R. Arimoto, Z. An, T. Chen, G. Zhang, G. Shu, and X. Wang, Atmospheric trace elements over source regions of Chinese dust: Concentrations, sources and atmospheric input to the Loess plateau, *Atmospheric Environment*, 27A, 2051-1067, 1993.
- Zhang, X., R. Arimoto, Z. An, T. Chen, G. Zhang, and B. Ray, Late Quaternary records of the atmospheric input of eolian dust to the center of the Chinese Loess plateau *Quaternary Research*, 41, 35-43, 1994.
- Zhang, X. Y., R. Arimoto, and Z. S. An, Dust emission from Chinese desert sources linked to variations in atmospheric circulation, *Journal of Geophysical Research*, 102, 28,041-28,047, 1997.
- Zhou, M. Y., Z. Chen, R. Huang, Q. Wang, R. Arimoto, F. Parungo, D. Lenschow, K. Okada, and W. Wu, Effects of two dust storms on solar radiation in the Beijing-Tianjin area, *Geophysical Research Letters*, 21, 2697-2700, 1994.

*In addition to these refereed publications, fourteen abstracts--⁹based at least in part on research supported this award--were

published.

b. W. C. Keene

i. NSF-ATM-9415559, \$168,267, 1 Sept. 1995 to 31 August 1998

ii. The Chemistry of Inorganic Chlorine in the Marine Boundary Layer at Bermuda During Spring

iii. Summary of Results. This grant supported an ancillary investigation of inorganic chlorine and bromine chemistry in the marine boundary layer in conjunction with a larger field intensive conducting under the auspices of the Atmospheric Ocean Chemistry Experiment (AEROCE). During April and May 1996, we measured HCl^* , Cl^* , and Cl_l with tandem mist chambers deployed over diel cycles at the AEROCE tower on Bermuda. The composition and number of size-segregated aerosols, non-methane hydrocarbons, SO_2 , reactive N gases, CO, O_3 , meteorological conditions, and transport were measured in parallel by independently funded investigators. North American emissions impacted the site during all sampling periods. Sea-salt aerosol pHs ranged from the mid 3s to the mid 4s but were essentially constant across the supermicron size spectrum of each sample. Cl and Br deficits relative to sea salt summed over size distributions ranged from 3% to 26% and from 12% to 81%, respectively. Average percentage Cl and Br deficits were similar during day and night and at high (>75%) and low (<75%) RH. HCl^* and Cl_l were highly correlated during most intervals, ranging from <30 to 1477 pptv; mixing ratios often peaked during mid-afternoon and decreased overnight. Cl^* ranged from <30 to 259 pptv; detectable mixing ratios were generally limited to periods when RH was greater than 75% and consistent diel variability was not evident. Interpretations of these results are reported in the cited literature below.

Human Resource Development: Students Trained: Melissa Southwell, Undergraduate Honors Program, 1996-97; Kristina Russell, Ph.D. candidate, 1997-present; Deborah Todd, MS candidate, 1997-present; Vaughan Turekian, Ph.D. candidate, 1997-present.

iv. Publications Resulting From the NSF Award. In addition to those mentioned below, results of this work were reported at 3 other international conferences.

Erickson, D. J., C. Seuzaret, W. C. Keene, and S.-L. Gong, A general circulation model calculation of HCl and ClNO_2 production from sea-salt dechlorination: The Reactive Chlorine Emissions Inventory, *J. Geophys. Res.*, 104, 8347-8372, 1999.

Keene, W. C., and D. L. Savoie, The pH of deliquesced sea-salt aerosol in polluted marine air, *Geophys. Res. Lett.*, 25, 2181- 2194, 1998.

Keene, W. C., and D. L. Savoie, Correction to "The pH of deliquesced sea-salt aerosol in polluted marine air," *Geophys. Res. Lett.*, 26, 1315-1316, 1999.

Keene, W. C., J. R. Maben, J. L. Moody, J. N. Galloway, D. L. Savoie, P. J. Milne, H. Maring, J. M. Prospero, D. J. Jacob, J. R. Merrill, B. G. Doddridge, R. R. Dickerson, The chemistry of inorganic Cl in the marine boundary layer at Bermuda during spring '96, Fall Meeting of the American Geophysical Union, San Francisco, Dec, EOS, 78(46), F123, 1997.

Keene, W. C., J. R. Maben, D. J. Savoie, R. Arimoto, J. T. Merrill, A. A. P. Pszenny, P. J. Milne, and J. N. Galloway, Inorganic halogens in surface marine air at Bermuda during spring, *J. Geophys. Res.*, in review, 1999.

Keene, W. C., R. Sander, A. A. P. Pszenny, R. Vogt, P. J. Crutzen, and J. N. Galloway, Aerosol pH in the marine boundary layer: A review and model evaluation, *J. Aerosol Sci*, 29, 339- 356, 1998

Milne, P. J., W. C. Keene, J. L. Moody, J. R. Merrill, A. Prados, B. G. Doddridge, and R. R. Dickerson, Chemistry of non- methane hydrocarbons in the marine atmosphere around Bermuda during the AEROCE III experiment, Fall Meeting of the American Geophysical Union, San Francisco, Dec, EOS, 78(46), F129, 1997.

Pszenny, A., W. Keene, C. O'Dowd, M. Smith, and P. Quinn, Sea salt aerosols, tropospheric sulfur cycling, and climate forcing, Newsletter of the International Global Atmospheric Chemistry Program, No. 11, pp. 6-12, MIT, Cambridge, Ma, 1998; (a similar version of this article appeared in the Global Change Newsletter, International Geosphere-Biosphere Programme, No. 33, pp. 13-19, Royal Swedish Academy of Science, Stockholm, 1998).

v. Description of Available Data. All data generated though this research effort have been distributed to participants in the experiment, are archived at the University of Virginia, and are available upon request to other investigators.

c. I. Sokolik

Dr. Sokolik has had no prior NSF support.

2. INTRODUCTION

Atmospheric scientists have increasingly turned their attention to the Asia/Pacific region because the concentrations of air pollutants have increased as a consequence of the rapid economic expansion and population growth in Asia (Hashimoto et al., 1994; Akimoto et al., 1994). Efforts are underway to address some of the adverse human health, environmental, and economic effects of urban air pollution (e.g., CICETE and UNDP, 1996), but most projections indicate that sulfur dioxide emissions, primarily from coal combustion, will continue to rise for the foreseeable future, perhaps increasing 5-fold from 1980 to 2010 (Worldwatch Institute, 1998). Currently, emissions of S-, N-, and C-containing compounds from coal combustion, biomass burning, and agriculture in eastern Asia are comparable to or greater than those in Europe and North America, but the emissions from eastern Asia are increasing at substantially greater rates than those in other regions. Within two decades, east Asian emissions will account for roughly one half of the S and N and roughly one third of C emitted globally from all anthropogenic sources (Galloway et al., 1998). These emissions already are having impacts; for example, the oxidizing capacity of the atmosphere over10eastern Asia and the western Pacific is changing rapidly as

the growing transportation sector raises the concentrations of nitrogen oxides to levels that will eventually approach those in Europe and North America (Elliot et al., 1997; van Aardeen, 1999).

Along with the concerns over chemical changes in the atmosphere over Asia is a parallel interest in the effects of these changes on climate, particularly in the radiative and climate forcing caused by aerosol particles. Rising anthropogenic emissions have increased aerosol concentrations and optical depths over much of Asia, and this has affected the amount of solar radiation absorbed and scattered back to space (Charlson et al., 1991; Penner et al., 1993; Andreae, 1995). Uncertainty in the magnitude of the forcing by anthropogenic aerosols on global and regional scales limits our understanding of how human activities affect climate (IPCC, 1996).

Dust storms that periodically blanket vast areas of the continent in the late winter and spring make the mixture of aerosols over Asia unique (Watts, 1969; Winchester et al., 1981; Iwasaka et al., 1983; Zhang, 1984; Zhang et al., 1993; Gao et al., 1992; Parungo et al., 1995). Mineral dust particles not only interact with solar and infrared radiation directly (Sokolik and Toon, 1996), but they also react with various trace gases, and through these reactions affect the cycles of other chemical constituents, especially aerosol sulfate and nitrate, with associated implications for climate (Dentener et al., 1996). Asian aerosols may exert significant radiative forcing over a large area of the Earth as a result of the strong outflow of Asia dust and pollution aerosol to the Central North Pacific and beyond (e.g., Duce et al., 1980; Uematsu et al., 1983; Braaten and Cahill, 1986; Arimoto et al., 1989; Prospero et al., 1989; Zhou et al., 1990; Jaffe et al., 1999, see also the PEM-West special issues of the J. Geophys. Res.-Atmospheres, Vol 101 D1, 1996 and Vol 102 D23, 1997).

3. SCIENTIFIC FRAMEWORK AND OBJECTIVES

a. Genesis of the Program

Interest in the chemical and climate-related changes in the atmosphere over eastern Asia has lead to the development of ACE-Asia, which is the third of the Aerosol Characterization Experiments (ACE) and a major multi-national field effort recognized by the International Global Atmospheric Chemistry (IGAC) Project. The primary objective of ACE-Asia is to reduce the uncertainty in the magnitude and effects of radiative forcing (defined as the imposed change in the heat balance caused by aerosols) over eastern Asia and the western North Pacific. A related goal for the program is to understand the multi-phase system at a level sufficient for developing defensible scenarios for radiative forcing and climate-change in the future.

ACE-Asia consists of three integrated components (1) the network-based studies of the sources and sinks of near surface aerosols and spatial and temporal distributions in their chemical, optical, and radiative properties, which are the focus of this proposal, (2) an intensive survey and study of aerosol evolution, processes and properties, and direct radiative effects, which will involve sampling from selected ground stations, aircraft and ships, and (3) intensive cloud-aerosol experiments, many of which are still in the early planning stages.

Plans for the program were developed during open planning meetings in Nagoya, Japan (1997) and Cheju, Korea (1998). Separate Science and Implementation Plans (SIPs) for the Network Studies and the Survey and Evolution Studies were subsequently submitted to NSF. The reviews of the SIPs were generally positive and recommended funding after deficiencies are addressed. Following a recommendation made at the most recent planning meeting in Kunming, China (November 1999), a site was established on the world wide web (<http://www.joss.ucar.edu/ace-asia/planning.html>) for posting information on the existing infrastructure at the network sites and for publicizing the interests of prospective PIs. Regional Site Coordinators have been identified for network management purposes, and their contact information has been posted on the web site. The website was also designed to be used for exchanging information relative to the development of network-related proposals to NSF by US investigators.

b. The ACE-Asia Network Goals

The overall hypothesis to be investigated for the ACE-Asia Network studies is that the emissions of anthropogenic materials in Asia have perturbed the atmosphere to such an extent that significant impacts of aerosols on climate are likely and even more likely to become stronger in the future. The activities presented in this network coordination proposal were designed to enable the ACE-Asia science team to better characterize the spatial and temporal (synoptic to interannual) variability of key aerosol chemical, physical and optical properties in near surface air over the study domain. Related studies will be conducted to better understand the removal of aerosols *via* wet deposition and the roles played by aerosols in the biogeochemical cycles of selected substances. The Network Studies SIP (available at <http://saga.pmel.noaa.gov/aceasia/>) lists examples of specific questions that will be addressed through the network studies, and these will be elaborated upon in the set of proposals being submitted to NSF.

The network data will be used to develop and test transport and chemistry models as well as models that simulate radiative effects of aerosols, these integrating tools will improve our ability to predict the effects of future emission scenarios in quantitative terms. Beyond their intrinsic value, the surface measurements made for ACE-Asia will be used for planning the ACE Asia aircraft and ship-based investigations, for putting the results of those experiments in a broader context, and for providing a database against which future changes can be evaluated. The overall goals for the Network studies as presented in the SIP are as follows:

Goal 1 Establish a framework of aerosol measurements that will form the underpinnings for the ACE-Asia intensive experiments and other regional studies, providing a climatological context and extending the

coverage of the ACE-Asia domain,

- Goal 2* Characterize the physical, chemical, optical and radiative properties of the atmospheric aerosols in the ACE-Asia region and understand the factors controlling the regional and temporal variability of these properties on synoptic to interannual time scales,
- Goal 3* Determine how regional aerosol sources and sinks (ionic, organic, and inorganic, including mineral aerosols) relate to the oxidation of aerosol precursor gases, air-sea exchange, and aerosol evolution,
- Goal 4* Determine the optical properties of major aerosol types by combining *in situ* measurements with remote sensing methods, and
- Goal 5* Use standardized and well characterized procedures to obtain the chemical and physical data needed to develop and validate reliable regional- to hemispheric-scale aerosol models.

c. The ACE-Asia Network Design: Sampling Stations and Strategies

The ACE-Asia network will be composed of two types of stations: basic and enhanced, with routine or intensive studies possible at any of the stations. Intensive studies will be coordinated with operations on mobile platforms, including the NCAR C-130 and the R/V Ron Brown. Participants at the Second ACE-Asia Planning Meeting in Cheju, Korea recommended that a program-standard IMPROVE (Interagency Monitoring to Protect Visual Environments) sampler be deployed as the minimal configuration of a basic station, and this recommendation was re-affirmed in Kunming (nb *this decision is not without controversy, however, as discussed below*). More complete and more advanced instrumentation and sampling equipment installed at the enhanced stations will be used to study (1) detailed aerosol chemical properties, including size-separated analyses for mineral dust and major ions; organic speciation; organic and elemental carbon; and chemical tracers, (2) aerosol optical properties (especially aerosol light scattering and absorption), aerosol optical depth, and radiative fluxes, and (3) wet deposition rates for aerosols.

The study domain (Figure 1) covers a broad area of Asia and the North Pacific: the eastern boundary of the network will extend to Hawaii because Asian aerosols, including mineral dust particles, are regularly observed at least that far from the source regions. The western boundary is being established as close as possible to the main dust source regions in the Chinese deserts, acknowledging the limitations on site selection imposed by logistical considerations. As continental outflow from Asia is a major issue for ACE-Asia, the southern boundary of the study domain will be at $\sim 20^\circ$ N, mainly in the interest of avoiding the marine aerosols brought to the continent by trade winds. The boundary to the north will be at $\sim 45^\circ$ N, again as a consequence of the program's focus on outflow.

Following the Kunming meeting, enhanced network sites were recommended for the following locations (see Figure 1): (1) at Zhenbeitai, suggested by the Chinese scientists as the most practical sampling site near a dust source region, (2) near Beijing in a heavy impacted interior region, (3) near Qingdao on the Asian coast, (4) near Lin'an, PRC which is upwind of (5) Cheju, Korea, a near-shore outflow site, and (6) on Hachijo, a Japanese island in the outflow region farther offshore than Cheju. Other major sites for ACE-Asia will be in Taiwan, either at Lan-yu or Mt. Bamboo, and at Hong Kong.

Basic stations will be located in Japan, Taiwan, Korea, and China. Related sampling programs will take place in throughout the region, including at Mondy (Russia), during some train experiments, also in Russia, and in Thailand (Inthano and Srinakhari).

d. Making It All Work or "The Devil is in the Details"

The operating plan for the ACE-Asia Network is for science teams from the countries where the sampling sites are located to obtain their own funding, to install and operate the necessary sampling equipment, and to analyze samples in regional or on-site laboratories. Therefore, most of the funding for the network is being provided in support of Asian national and regional interests (e.g., acid rain research). In addition, some stations have been in operation for more than a decade, and it is important to recognize that scientists at many of the operational sites are already investigating various aspects of aerosol chemistry, physical properties, and/or cycling. Trace gases, especially ozone and carbon monoxide, also are being studied at a number of the existing sites, and in some cases these analyses have been continuing over a number of years.



Figure 1. Prospective stations for the ACE-Asia Network. Enhanced sites are marked with a star, basic stations with a circle

The efforts proposed herein focus on coordinating the ongoing and planned research activities at the Network sites. The Network at present is loosely organized, and it is held together mainly by the interests of the scientists in aerosol research. In practical terms, the differences in research foci among sites means for example that the aerosols for chemical analyses may well be collected with different samplers over different intervals on different schedules with analyses by different techniques. Some coordination among some of the ground station sites will be facilitated by the East Asia Pacific Regional Experiment (APARE), which is an IGAC activity, but no formal measures or plans are yet in place. Furthermore, different instrumentation will be used for studies of aerosol optical properties and radiative fluxes at the various sites, and funds are not available to standardize the instrumentation at all sites. This is obviously a less than ideal situation from a programmatic standpoint, and we are confident that a relatively modest coordinating effort will facilitate the development of a robust regional database suitable for addressing the ACE-Asia objectives. Recognizing the benefits of coordinating the activities at the Network sites, the PIs for this proposal have developed plans to make ACE-Asia a cohesive program. The specific objectives of this proposal are as follows:

- To develop the Network infrastructure and improve the representativeness of the measurements made at the sites,*
- To coordinate and standardize the measurement activities for studies of aerosol composition and mass, aerosol optical properties and radiative fluxes, and wet deposition,*
- To intercompare analytical methods and instrumentation,*
- To provide training where desirable,*
- To assist in assuring and controlling data quality,*
- To develop a data archive,*
- To develop resources for teaching, training, and learning with respect to radiative processes, atmospheric chemistry and global change*

The success of these efforts will largely depend on the cooperation of the Regional Site Coordinators and the scientists working at the individual sites. Attached as Section I, Supplementary Documentation, are letters of support from each of the Regional Coordinators. Summary information is provided in Table 1.

Table 1. Regional Site Co-ordinators for the ACE-Asia Network

Region	Network Co-ordinator	Affiliation	Contact Information
People's Republic of China	Dr. Zhang Renjian	Institute of Atmospheric Physics	zrj@mail.iap.ac.cn Phone: 86-10-6235-9642 Fax: 86-10-6202-8604
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e. Relationships to Other Programs

APARE has endorsed both ACE-Asia and NASA's TRACE-P Mission (TRANsport and Chemical Evolution over the Pacific). Primarily an aircraft mission, TRACE-P is scheduled to be in the field in March-April 2001, and it follows on the NASA sponsored PEM-West experiments (Pacific Exploratory Mission—Western Pacific) PEM-West A & B involved aircraft flights over eastern Asia and the western Pacific in the September-October 1991 and March-April 1994, respectively, and longer-term studies at a network of ground stations. As described at their network site (<http://www-as.harvard.edu/chemistry/trop/tracep/>), TRACE-P will focus on the materials advected out over the Pacific Ocean, especially radiatively active trace gases and aerosols, and on the chemical evolution of the air masses.

Studies for ACE-Asia also will complement ongoing and planned studies being undertaken for the China Metro-Agro Plex experiment (China MAP, <http://www-wlc.eas.gatech.edu/chinamap.html>), the Global Atmosphere Watch (GAW, http://www.wmo.ch/web/arep/gaw_pamphlet.pdf), and various national and regional monitoring programs, including EANET (East Asia Network for Environmental Monitoring, <http://www.eic.or.jp/eanet/en/index.html>) which is organized by the Japanese EPA. None of these other programs has the same explicit emphasis on aerosols and radiative forcing as ACE-Asia.

4. PROPOSED PROGRAM

The Network coordination program proposed here consists of six main components: the first deals with developing the network infrastructure while the next three are concerned with measurements and determinations of aerosol chemical properties and mass loadings; aerosol optical properties and radiation; and wet deposition, respectively. These three measurement sections share some common coordinating activities, specifically conducting site visits, developing standard operating procedures, and establishing guidelines for quality assurance and quality control, and establishing a Network web site: these are introduced under the infrastructure development section. Each of the measurement sections differs from the others somewhat in their details, however, and therefore the specifics for the measurement sections are presented separately. A fifth component deals with data archiving, which is an activity to be carried out in collaboration with the Joint Office of Scientific Support (JOSS) and therefore only briefly discussed here (the specifics of the data archive will be described in detail in the JOSS proposal to NSF). The sixth and final component of the program is the development of resources for teaching, training, and learning with respect to radiative processes, atmospheric chemistry and global change.

a. Activities to be Undertaken

i. Infrastructure development

Tower installation (W. Keene)

Reliable optical and radiation measurements as well as chemical characterization and analysis of near-surface marine air at coastal sampling stations may be compromised by locally generated sea-spray, dust, and plant material (e.g., Galloway et al., 1988). Such problems are exacerbated when instruments are deployed at the tops of coastal cliffs where enhanced turbulence may erode dust and plant debris from cliff faces thereby significantly altering the chemical composition and physical characteristics of local air (e.g., Ayers and Ivey, 1988; Ayers et al., 1999). In near-surface air at Cape Grim, Tasmania, for example, locally produced crustal Na⁺ accounts for about one third of total particulate Na⁺ (Ayers et al., 1999). Such large local influences substantially increase uncertainties in quantifying concentrations of non-sea-salt constituents based on sea-salt tracers such as Na⁺ (e.g., Keene et al., 1986). The presence of significant locally produced dust could also seriously compromise attempts to investigate the physiochemical properties and evolution of mineral aerosol on a regional basis. To minimize the effects of local wind-generated contaminants, many research programs (e.g., SEAREX, AEROCE) have installed walk-up, aluminum, scaffolding towers (typically 20 m high) to raise sampler inlets above the near-surface turbulence zone where such local influence are most severe.

Reliable, regionally representative measurements of the chemical composition of aerosols, aerosol optical

properties, and precipitation at sampling stations on coastal cliffs in ACE-Asia outflow regions will require such towers. We consider the Kosan site on Cheju-do, Korea to be the most important location in this regard. The sampling station is located at the top of a 71.21-m tall coastal cliff. This station is centrally located in the outflow region and many continuous and intensive investigations will focus on this location (e.g., see appended letter from H. Sievering). Consequently, we propose to install a standard 20-m, heavy-duty, walk-up aluminum scaffolding tower with 2 topside outrig platforms at this station. Topside outrigger balconies (1.8 m x 1.8 m each) will be needed to support the numerous instrument deployments planned for the program, especially during sampling intensives. These towers are manufactured by Horizon High Reach, Inc., and have been previously deployed at numerous marine locations (Mace Head, Ireland; Bermuda; Barbados; Ohau, Hawaii; American Samoa; Enewetak Atoll; 90 Mile Beach, New Zealand; among others) as part of past and ongoing research efforts. The structures are strong (several have weathered hurricanes), resistant to corrosion, modular, and relatively easy and inexpensive to erect and dismantle by small crews of workers. The tower will be installed in late 2000, left in place for the 3-year duration of the larger ACE-Asia experiment, and subsequently, dismantled and returned to the U.S. in late 2003 or early 2004.

Considerable resources have already been committed by collaborating institutions for the proposed tower deployment. The University of Virginia (UVA) will provide one complete tower (excluding guys and outrig platforms) for the duration of the experiment (see appended letter from J. Galloway). This tower was installed in the Shenandoah National Park in the late 1980's as part of the Mountain Cloud Chemistry Project (MCCP) and is in excellent condition. A sister tower was removed last year by one of the PIs (WCK) and re-erected at another location. UVA has also allocated funds (primarily salary) to dismantle the tower. Funds are requested through UVA's component of this proposal to hire a helicopter to lift the dismantled tower components from the current sampling station on a steep mountain side in the Shenandoah National Park to a nearby staging area accessible by vehicles. A helicopter also lifted the tower sections into the park at the beginning of the MCCP; the steep terrain and lack of vehicular access to the tower site make it impractical to remove the components by other means.

The Meteorological Research Institute of Korea (METRI) will pay most costs for installing the tower at the beginning of the project, operating and maintaining the facility for 3 years, and removing the tower at the end of the project (see appended letter). Specifically, they will 1) off load and transport the tower components from a port on Cheju-do to the sampling site at the beginning of the experiment and will transport them to the port and load it on a ship at the end of the experiment, 2) layout and install the concrete foundations and guy anchors as per manufacturer's specifications, 3) provide work crews to assist in erecting and dismantling the towers, and 4) periodically retension guys as per manufacturer's specifications.

Additional funds will be required to cover the following costs for deploying the tower:

- 1) Two outrig platforms, guys, anchor rods, and associated hardware required to configure and deploy the tower.
- 2) Roundtrip shipping from the US to Cheju-do.
- 3) Salary for one of the PIs (WCK) and an experienced technician to supervise installation and removal of the tower.
- 4) Travel the PI and technician to supervise installation and removal of the tower.

Funds for items 2 and 4 will be request through the JOSS proposal for ACE-Asia and those for the other items are budgeted though UVA's component of this proposal. At the time this proposal was submitted, the Ace-Asia convenors were negotiating with METRI administrators concerning additional infrastructure upgrades (more power, a laboratory container, etc.) at the site.

Site visits (Arimoto, Keene, Sokolik, Galloway)

No matter how good the analytical methods, the data from any given sampling site can be compromised by poor site selection, contaminants from local sources, malfunctioning equipment, or operator errors when collecting the samples. Therefore site visits by the PIs or their designees will be conducted to ensure the samples and data from the Network sites are as representative and as high in quality as possible. The site visits will take place as early in the program as practical, ideally before the end of 2000. To the extent possible, these visits will be coordinated with the ACE-Asia science team meetings. For example, some members of the ACE-Asia group from Taiwan are organizing a conference in the fall of 2000, and the next ACE-Asia meeting may be held there. If so, a visit to the enhanced site in Taiwan could be arranged at little expense beyond what would be requested to attend the science team meeting. Similarly, if funded, some of the shipboard/multiphase chemistry operations would be staged out of Japan, and a visit to the enhanced site in Japan, (which is yet to be named but probably at Hachijo) , could be arranged at modest additional expense. J. Galloway's frequent visits to China in association with other ongoing projects (see biosketch) will provide opportunities for additional site visits at no cost to this program.

The objectives of these visits are to work within the existing infrastructure to the extent possible and to make observations with respect to those factors affecting sample integrity and data quality for each of the three measurement activities listed above. We will document the characteristics of each collaborating station including the following: latitude, longitude, elevation, average annual precipitation, regional landscape type, potential local sources of contamination (coal and biomass burning, agricultural fertilizers, major highways, local dust, overhanging vegetation, etc.),

samplers and instrumentation, sampling and analytical protocols, and primary operator contact.

Specifically, during year one of the program, one or more of the PIs for this proposal or one of the ACE conveners will inspect and document each established enhanced sites and as logistics permit, nearby 'basic' network stations. It would be prohibitively expensive to visit some of the more remote stations in the basic network, and we will instead document those sites based on solicited photographs, maps, and responses by operators to detailed questionnaires. Visits to regional analytical laboratories also will be conducted if feasible during the site inspections. We note that site visits are potentially a sensitive issue especially because the various stations have been established for different programs and hence have different scientific goals. Any recommendations with respect to site operations must be made with recognition of the scientific goals and the practical and financial limitations for each site.

Preparation of standard operating procedures (Arimoto, Keene, Sokolik, Galloway)

For maximum data comparability, standardized sample collection intervals and frequencies will be documented in recommended standard operating procedures (SOPs). Related SOPs will be developed for the sample processing and the instrumental methods used for chemical analyses where practical. As often is the case, decisions about the particulars of the SOPs must take into account the concentrations of the substances of interest (or the signals) relative to the background, the logistics of sample collection and processing, the availability of personnel for station operations, and the expenses associated with collecting and analyzing the samples.

Quality assurance and quality control (QA/QC) (Arimoto, Keene, Sokolik, Galloway)

The development and implementation of a quality assurance and quality control programs complements the proposed efforts to coordinate site operations, sampling and analysis. This is another potentially sensitive undertaking, and it will be important to work with the participating scientists in providing guidance for assuring and maintaining data quality. Some components of the quality assurance plans for the measurement activities will depend on the data quality objectives that will be established through discussions among participants; other components of the QA plans will involve data validation and verification and data archiving procedures. QA/QC for the chemical analyses will involve the analysis of reference materials, replicates, sample splits, blanks, etc. as detailed in the measurement sections that follow.

ACE-Asia Network web site (All PIs: Sokolik, lead)

A web site will be established for exchanging information, for coordinating network operations, and for providing links to other ACE activities. Electronic copies of the SOPs and QA plans will be posted on this web site to provide access for all participating sites and laboratories. Links also will be provided to other ACE-Asia activities, especially the shipboard and aircraft studies, and to regional programs, institutions, etc. as desired. This site also will have links to a separate and secure data archive (maintained by JOSS under separate funding), and access will be provided to the educational materials developed for the program (see section 5a).

ii. Aerosol Chemical Properties and Mass Loadings (Arimoto)

As the ACE acronym implies, one of the fundamental activities for the program is to produce a detailed characterization of the east Asian/Pacific aerosol in terms of mass loadings and chemical composition (considering ionic; inorganic; and to the extent possible, organic components). Even the most basic network studies will benefit from the coordination of efforts through the following: (1) the recommendation of program-standard sampling equipment and, if necessary, intercomparisons against other samplers, (2) the development and implementation of standard operating procedures for sample collection, processing, and analysis, (3) the establishment of appropriate quality assurance/quality control procedures, and (4) the organization of a system for archiving data. These are the specific coordinating activities to be undertaken at CEMRC/NMSU for this proposal and discussed in detail below. Final decisions and products for each of these activities will be made after consultation with the regional site coordinators, but some general strategies and tentative plans can be outlined here.

Aerosol samplers

Following a series of meetings and discussions, the IMPROVE sampler was chosen to be the ACE-Asia Network standard. This choice was based on several practical and scientific considerations, including (a) IMPROVE samplers are readily available and at a reasonable cost, (2) the samplers are versatile and can be configured for multiple types of analyses, (3) there is an enormous data base on PM_{2.5} mass loadings and chemical composition from IMPROVE and other large networks, and (4) several of the dominant aerosol types, especially sea salt and mineral dust, are well represented in the PM_{2.5} fraction. Despite these advantages, the choice of sampler has been criticized on the grounds that submicrometer particles are the most optically important size fraction and therefore a 1 µm size cut would be preferable to the PM_{2.5} size fraction. Even though aerodynamic size and optical size are not related in any simple manner, the need for information on the optically important size fraction is undeniable, and therefore the performance of the IMPROVE sampler needs to be evaluated as part of the ACE-Asia Network studies. This will be readily done at the one or more of the enhanced stations where cascade impactors and optical particle sizing instrumentation will be co-located with IMPROVE units. In addition, there are engineering efforts now underway to adapt the IMPROVE samplers for collection of the PM₁ fraction (T.

Cahill, U. CA, Davis), and those modifications to the samplers will facilitate side-by-side comparisons of the data for the IMPROVE PM_{2.5} vs. PM₁ size fractions.

Aerosol sample collection, processing, and analysis

A set of standard operating procedures has been developed for various research projects conducted by the PI, and these will form the basis for the Network SOPs for aerosol sampling processing and analysis. The format of these SOPs will include the following where applicable: (1) title, (2) signatures, (3) purpose, (4) scope and application, (5) miscellaneous notes and precautions (including chemical hygiene, toxic chemicals or safety issues), (6) definitions, (7) responsibilities, (8) quality control limits, (9) measurement principle, (10) apparatus, (11) instrument, (12) reagents, (13) instrument detection limits, (14) method detection limits, (15) standards, (16) calibrations, (17) procedures (i.e., detailed step-by-step instructions), (18) calculations, (19) forms and paperwork, (20) corrective action procedures, including procedures for secondary review of information being generated, and (21) references.

For years the IMPROVE network has relied on 24-hr collections twice weekly (Wednesday and Saturday), and this is a realistic starting model for the ACE-Asia Basic Network. The Enhanced stations will follow the same model as a minimum from routine operations, but more frequent sampling over shorter time intervals (twice daily or shorter) will be encouraged. During the intensive campaigns, the recommended intervals for aerosol sampling, including cascade impactor sampling, will be twice daily or shorter.

Aerosol sample processing and analysis will be done in on-site or regional laboratories using SOPs that will be developed for this section of the proposal. Again the CEMRC/NMSU SOPs developed in the environmental chemistry laboratory will be used as starting points, and the analytical SOPs will contain specific guidelines with respect to checks for reagent purity, prescriptions for the analysis of blanks (field blanks, laboratory reagent blanks, etc), the analysis of suitable reference materials (certified reference materials, laboratory fortified matrix samples, performance test samples, etc.), calibration and performance of instrumentation, and calculation of the results.

Separate SOPs will be written for (a) gravimetric analyses, (b) major ionic constituents, including but not limited to nitrate, sulfate, methanesulfonate, chloride, and (c) trace elements, including at least aluminum, sodium, and iron. Clearly, not all of the laboratories involved in ACE-Asia will have the same equipment and instrumentation, but some basic guidelines for recoveries, instrument performance, etc. are worth establishing.

Quality assurance and quality control for aerosol chemistry

To ensure comparability of results among stations, we propose that the NMSU laboratory serve as a central reference laboratory for the aerosol chemical properties and mass analyses. The model proposed for this important exercise would have each ACE-Asia regions designate a reference laboratory for the program, with the following comparisons made between labs

- ◆ Periodic (twice annual) analysis by all labs of audit solutions provided by the central lab
- ◆ Periodic (twice annual) analysis by the central lab of field-sample and field-blank splits from the regional labs
- ◆ Periodic (twice annual) analysis by the regional labs of field-sample and field-blank splits from each participant lab
- ◆ Routine analysis of field blanks by all labs.
- ◆ Periodic (annual) summary reports by the central lab detailing analytical performance by each regional lab.
- ◆ Periodic (annual) summary reports by each regional lab detailing analytical performance by each of their respective participant labs.

This approach has the advantage of minimizing duplication of analytical cross-checks and from a more practical standpoint, efficiently using the resources available for station operations.

iii. Aerosol optics and radiation (Sokolik)

The ACE-Asia Network SIP has identified measurements and instrumentation required to meet the ACE-Asia goals with respect to aerosol optics and radiation (see <http://saga.pmel.noaa.gov/aceasia/>). Due to the complex nature of tropospheric aerosols in the ACE-Asia region, the diversity of optics and radiation instruments, and known deficiencies of measurement techniques, the proper coordination of measurements, data quality control, and data interpretation will be a key requirement for successful accomplishment of the ACE-Asia tasks in these areas. The specific activities relevant to optics and aerosol measurements proposed under this project are briefly described below.

1) Developing standard operating procedures (SOPs) for aerosol optics and radiation measurements

As discussed above in section 4.a.i, we propose the development of a standard operating procedure for each type of measurement to improve the overall synergism of ACE-Asia data. Table 2 lists the aerosol optics and radiation properties and instrumentation recommended in the Science and Implementation Plan for the long-term observations at the ACE-Asia Network. Also some critical issues that must be resolved in SOPs are briefly highlighted.

The starting point for optics and radiation measurements will be a development of a measurement survey questionnaire. The questionnaire will obtain detailed information on the types of the instruments, calibration procedures, data collection frequencies, and data retrieval methods employed¹⁷ by different ACE-Asia teams. The questionnaire will be

posted at the Network web site and distributed among PIs during July-August 2000. The information obtained from the questionnaire will provide a basis for SOPs development. In the SOPs, recommendations will be made regarding real-time operational procedures, data frequency and resolution, dataset size and format, etc. A complementary strategy for quality control and calibration procedures is presented below.

Table 2 Aerosol Optical and Radiation Measurements Recommended for the ACE-Asia Network Sites.

Parameter	Instruments	Issues
Aerosol spectral optical depth	Sunphotometers	Operating wavelengths; Correction for Raleigh scattering and gaseous absorption; Cloud screening.
Aerosol light scattering coefficient	Nephelometers	Operating wavelengths; Control relative humidity and temperature; Control size-cut; Control flow rate; Angular truncation.
Aerosol light absorption coefficient	Aethalometers, Absorption Photometers	Operating wavelengths; Control size-cut; Control flow rate.
Direct solar radiation	Cavity radiometers; Pyrheliometers	Cloud screening; Solar-tracking accuracy; Poor weather protection; Body temperature control.
Global solar radiation	Pyranometers	
Diffuse solar radiation	Shaded pyranometers	
Long-wave radiation	Pyrgeometers; Pyrradiometers	Cloud screening; Dome heating control.
Sun and sky radiances	Sun/sky radiometers	Cloud screening.

2) Organization of a workshop on instrument intercalibration and intercomparison.

Although relative measurements provide important information and will be used to address some of the ACE-Asia questions, having the capability to make optics and radiation observations of sufficient precision and accuracy is necessary to meet the overall ACE-Asia objectives. We propose the organization of a workshop on instrument intercalibration in Boulder, CO, USA, using the aerosol optics and radiation laboratory (headed by Prof. Sokolik) at University of Colorado as well as NOAA/CMDL facilities or/and at one of the ACE-Asia network sites (e.g., Kosan, Korea). The goals of the workshop will be to develop uniform calibration procedures and perform an intercomparison of the instruments.

For some radiation instruments, calibration procedures have been developed and successfully adopted by various monitoring programs. For instance, solar radiometers can be calibrated relative to the World Radiation Reference following a calibration procedure developed by an international Baseline Surface Radiation Network (BSRN), sponsored by the World Climate Research Programme (Ohmura et al., 1998). Also, a calibration procedure is available for sun/sky radiometers, which are currently deployed at the AERONET (Aerosol Robotic Network) stations (Holben et al., 1997). However the procedure relies on the Langley method and, hence, requires very clean and stable atmospheric conditions (such as mountain-top sites). For ACE-Asia we will perform calibration by comparisons with well-calibrated radiation instruments available in the aerosol optics and radiation laboratory and NOAA/CMDL.

The measurements of aerosol optics (i.e., aerosol light scattering and absorption coefficients) are currently performed at various sites around the world and commercial instruments are readily available. However, some deficiencies of these measurement techniques may become crucial in the case of Asian aerosols when both large non-spherical absorbing mineral particles and small strongly absorbing carbonaceous particles are abundant. In particular, establishing the equivalence among different instruments measuring same quantity should be investigated. We expect that several types of nephelometers will be operated at the ACE-Asia network sites (such as an integrating nephelometer and an open-air nephelometer manufactured by the TSI, Inc. and ARS, Inc., respectively). Both instruments can be calibrated with clean-air or CO₂ gas (Anderson and Ogren, 1998); however, due to the specific design and instrument characteristics, side-by-side intercomparisons of these instruments are required. Furthermore, as demonstrated with field data from a desert station (e.g., Pirogov et al., 1992), it is important to correct nephelometric data for angular truncation errors, size dependence of the nephelometric response, and RH-induced variations among others. These issues will be fully addressed at the proposed workshop.

The measurements of light absorption are currently performed by two commercially available instruments: aethalometers and absorption photometers. Although both instruments employ a filter-based technique, the equivalency of these measurements (as well as other absorption measurements) remains to be fully established. Moreover, both types of instruments have serious problems in calibration and data interpretation (e.g., Bond et al., 1999). We intend to

investigate the equivalence between these instruments and recommend data interpretation procedures during the workshop.

3) Quality control of optics and radiation data and the data archive

We anticipate that the PIs will be primarily responsible for data quality control and regular instrument calibration. However, based on experience of other long-term observation programs (e.g., BSRN/WMO), we are planning to perform several tests of time-series before archiving data sets. This quality control procedure will be based on several criteria such as physical possible ranges, likelihood of occurrence, concurrent trends, comparison with model computations, and examination of time series (e.g., Ohmura et al., 1998). After quality control checks, all optics and radiation data with quality flags will be archived in a central location (JOSS/UCAR) to facilitate the exchange of information among participants and programs as discussed in section 4b, below.

4) Survey the existing optics and radiation data acquired over the ACE-Asia domain

We will survey the existing optics and radiation data sets acquired from ground-based measurements across the ACE-Asia domain. This activity will strongly depend on the support from the scientists in participating countries. Some information on radiation measurements performed during the last decade in China has been already reported at the ACE-Asia science team meeting in Kunming.

Also we will survey the existing lidar measurements (e.g., a lidar network located in Japan).because this provides valuable information about the aerosol vertical structure, which can be used for interpretation of other aerosol optical and radiation measurements as well as for radiation transfer models. The information on existing measurements in the ACE-Asia region will provide a useful climatological framework for the Network aerosol optics and radiation measurements.

iv. Wet Deposition (W. Keene, J. Galloway)

Preexisting measurement programs in the region will provide the backbone of the ACE-Asia wet-deposition network. These existing stations will be augmented by independently funded measurement programs at new sampling stations such as that planned at Hachijo and on ships at sea. The primary objectives of the effort proposed herein focus in organizing and characterizing operations at existing stations and quality assuring resulting data. This objectives will be accomplished through 4 major, interrelated activities briefly described below.

- (1) We will coordinate contributions of data to the ACE-Asia database from existing and new measurement programs in the region. We have already started this process through discussions during past ACE-Asia planning meetings and the posting of a sampling-station template on the ACE-Asia web site (<http://www.joss.ucar.edu/ace-asia/planning.html>).
- (2) We will develop and facilitate implementation of standard collection and processing protocols for those stations that are able follow them (i.e., new stations, stations at which a dedicated ACE-Asia samplers may be installed, or stations that have the flexibility to deviate from current protocols). These protocols will be modeled after those used by the AEROCE program (e.g., Galloway et al., 1993) and will specify daily collection of wet-only precipitation followed by immediate preservation with a biocide. The format for the “standard” protocols will be similar to that described above for aerosols. We will also compile and archive protocols for those sites that are required to operate using different procedures thereby facilitating data analysis.
- (3) We will implement a quality assurance program for the 5 major regional laboratories at which most samples will be analyzed (Korea, Japan, Peoples Republic of China, Taiwan, and Hong Kong) and for any other laboratory involved in ACE-Asia that wishes to participate. This program will be similar in structure to that described above for aerosols. We will periodically (2 times per year) distribute to each laboratory a set of three blind audit solutions containing regionally representative and known concentrations of H^+ , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , NH_4^+ , NO_3^- , SO_4^{2-} , Cl^- , $HCOO^-$ ($HCOO^- + HCOOH_{aq}$), and CH_3COO^- ($CH_3COO^- + CH_3COOH_{aq}$) traceable to the National Institute of Standards and Technology, 2) periodically (2 times per year) analyze sample and field-blank splits from one or more field sites under the direction of each participating laboratory, 3) evaluate performance based on analysis of the above information, and 4) communicate results to participating laboratories.
- (4) We will collaborate with JOSS in developing a data base for precipitation composition, corresponding wet-deposition fluxes, and associated QA information characterizing laboratory performance. The data base will include all descriptive information [station code, sample ID number, sampling protocol (daily, event, weekly, other), on/off dates and times, sampler type, method of sample preservation between collection and analysis, precipitation amount, precipitation type (rain, hail, snow, mixed)] and the corresponding analytical results reported by participating laboratories. Diagnostic flags will be included to facilitate data analysis and interpretation by users. Examples of diagnostic flags include: adherence to 'optimal' protocols; adherence to standard network protocols; ion-balances within +/-15%; participation in QA program; all tested analytes in audit solutions and sample splits within +/-15% of expected values for preceding QA evaluation; and all tested analytes in field blanks <2 uM for preceding QA evaluation. The above activities will produce a database of characterized quality for wet-deposition fluxes in the region. These data will be essential in constraining emission fluxes and modeling the chemical and physical evolution of aerosols across the ACE-Asia domain.

b. Network Data Archive

Principal investigators from any site within the ACE-Asia domain who are able to perform the relevant measurements and who are willing to abide by the guidelines for authorship will be encouraged to submit their data to the archive and to become jointly involved in the interpretation of the network data. One advantage to implementing a network-wide QA/QC program is that aspects of data quality can be easily characterized with flags; this procedure facilitates the subsequent filtering of data by users. This will provide those interested in using the data with an indication of data quality. The format of the data archive, the specifications of which data are to be included in the archive, and the mechanisms for entering data into the archive and for accessing data will be established in cooperation with JOSS and through interactions with the site operators.

Maintaining the data archive is an important activity because this comprehensive regional network data base will have benefits that extend long past the ACE-Asia time frame. The organization of a dedicated web site will provide access to quality-controlled data sets that can be used by the larger scientific community. The same web site that was set-up for exchanging information and developing proposals will be used for archiving the data.

5. BROADER IMPACTS

a. Teaching, training, and learning

The complexity of emerging problems in atmospheric chemistry and climate requires highly skilled specialists who have a broad education including both theoretical modeling and experimental work. International field experiments such as ACE-Asia provide an invaluable experience for the education of students and researchers.

This project will provide a wealth of materials that can be used for educational purposes. In particular, Prof. Sokolik will make extensive use of the data in her courses on atmospheric chemistry and solar and thermal radiation. Chemical measurements and related analytical methods will be used for the course “Air Chemistry and Pollution” (ATOC 3500), which Prof. Sokolik developed and teaches at the U of CO. Full lecture notes are available on the website: <http://irina.colorado.edu> (under teaching). Several professors in the US and abroad have used these notes as part of their course curricula. This course was also selected to be used as a basis for the IGAC atmospheric chemistry on-line course.

Interpretation of radiation measurements performed during ACE-Asia will be used for class projects in another course to be taught by Prof. Sokolik, “Radiative Processes in Planetary Atmospheres” (ATOC 5560). This course covers basic physics and computational methods of radiation transfer of solar and infrared radiation. The students will be learning how to combine radiation measurements and radiative transfer codes to estimate the radiative impact of aerosols (e.g., radiative forcing by Asian aerosols, effects of Asian aerosol on radiative budget at the surface, etc.).

Our efforts will also help train new atmospheric scientists, especially the students involved in the project. Two graduate students at the U of CO at Boulder (supervised by Prof. Sokolik) will be involved part-time in this proposal. These students will participate in site inspection and survey the existing radiation data sets over the ACE-Asia region. They also will be involved with data quality control and the data archive. Students will work on intercomparison and calibration of instruments.

Students and Prof. Sokolik will establish and maintain a dedicated web site to provide access for the educational materials discussed above.

b. Partnerships

The proposed activities will establish a unique long-term atmospheric chemistry network and build partnerships among scientists from a number of the Pacific Rim countries, and these two accomplishments will be a major benefit to the atmospheric sciences community. The intercomparisons of methods and intercalibration of instruments planned as activities for this proposal will provide hands-on training for researchers from the participating countries. The issuance of SOPs will provide guidelines for sampling and analysis that are applicable to other atmospheric chemistry projects and possibly transferable to studies of other types of environmental media.

In many respects the activities proposed here can be viewed as a service to the atmospheric community at large, and indeed one of the main attractions of this proposal to the PIs is the unique opportunity to work with scientists from halfway around the world. It is also worth pointing out that participation of students in this type of coordination proposal provides a unique opportunity for them to learn how science is organized and conducted within the scope of large international field experiments.

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- Prospero, J. M., M. Uematsu, and D. L. Savoie, Mineral aerosol transport to the Pacific Ocean, in *Chemical Oceanography*, vol. 10, J.P. Riley, R. Chester and R. A. Duce (Eds), Academic, San Diego, Calif., pp. 188-218, 1989.
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E. BIOGRAPHICAL SKETCHES (IN ALPHABETICAL ORDER)

Richard Arimoto (New Mexico State University)

Professional Preparation

University of Delaware, B.A. (Biology), June 1974
 University of Delaware, M.S. (Biology), June 1977
 University of Connecticut, Ph.D. (Biology), May 1981

Appointments

Senior Scientist, Carlsbad Environmental Monitoring & Research Center, New Mexico State University, FEB 97–Present

Associate Editor, *J. Geophysical Research-Atmospheres*, 1988 to 1997 and 1998–Present

Secretary and Program Committee Member, Atmospheric Sciences Section, American Geophysical Union 1996 to 1998

Associate Research Professor, Center for Atmospheric Chemistry Studies, Graduate School of Oceanography, University of Rhode Island, Narragansett, APR 92–FEB 97

Associate Marine Scientist, Center for Atmospheric Chemistry Studies, Graduate School of Oceanography, University of Rhode Island, Narragansett, MAY 87–APR 92

Environmental Science and Engineering Fellow, American Association for the Advancement of Science, Washington, D.C, Special consultant to the U.S. Environmental Protection Agency, JUN 87–AUG 87

Five Most Closely Related Publications

- Arimoto, R., B. J. Ray, N. F. Lewis, U. Tomza, and R. A. Duce, Mass-particle size distributions of atmospheric dust and the dry deposition of dust to the remote ocean *J. Geophys. Res.*, *102*, 15,867-15,874, 1997.
- Arimoto, R., R. A. Duce, D. L. Savoie, J. M. Prospero, R. Talbot, J. D. Cullen, U. Tomza, N. F. Lewis, and B. J. Ray, Relationships among aerosol constituents from Asia and the North Pacific during PEM-West A, *J. Geophys. Res.*, *101*, 2011-2023, 1996.
- Zhang, X. Y., R. Arimoto, G. H. Zhu, T. Chen, and G. Y. Zhang, Concentration, size-distribution and deposition of mineral aerosol over Chinese desert regions, *Tellus*, *50B*, 317-330, 1998.
- Gao, Y., R. Arimoto, R. A. Duce, X. Y. Zhang, G. Y. Zhang, Z. S. An, L. Q. Chen, M. Y. Zhou, and D. Y. Gu, Temporal and spatial distributions of mineral aerosol and its total deposition over continental China and the China Sea, *Tellus*, *49B*, 172-189, 1997.
- Chen, L., G. R. Carmichael, M. Hong, H. Ueda, S. Shim, C. H. Song, Y. P. Kim, R. Arimoto, J. Prospero, D. Savoie, K. Murano, J. K. Park, H. Lee, and C. Kang, Influence of continental outflow events on the aerosol composition at Cheju Island, South Korea, *J. Geophys. Res.*, *102*, 28,551-28,574, 1997.

Five Other Significant Publications

- Arimoto, R., R. A. Duce, J. M. Prospero, D. L. Savoie, R. W. Talbot, J. E. Dibb, B. G. Heikes, B. J. Ray, N. F. Lewis and U. Tomza, Comparisons of trace constituents from ground stations and the DC-8 aircraft during PEM-West B, *J. Geophys. Res.*, *102*, 28,539-28,550, 1997.
- Arimoto, R., J. A. Snow, W. C. Graustein, J. L. Moody, B. J. Ray, R. A. Duce, K. K. Turekian, and H. B. Maring, Influences of atmospheric transport pathways on radionuclide activities in aerosol particles from over the North Atlantic, *J. Geophys. Res.*, *104*, 21,301-21,316, 1999.
- Arimoto, R., R. A. Duce, B. J. Ray, W. G. Ellis, Jr., J. D. Cullen, and J. T. Merrill, Trace elements in the atmosphere over the North Atlantic, *J. Geophys. Res.*, *100*, 1199-1213, 1995.
- Arimoto, R., Y. Gao, M. Zhou, D. S. Lee, L. Chen, D. Gu, and Z. Wang, Atmospheric deposition of trace elements to the Western Pacific basin, in *Atmospheric Deposition of Contaminants to the Great Lakes and Coastal Waters*, edited by J. E. Baker, SETAC Press, Pensacola, FL, pp. 209-225, 1997.
- Huang, S., K. A. Rahn, R. Arimoto, Semiannual cycles of pollution at Bermuda, *J. Geophys. Res.*, *104*, 30,309-30,318, 1999.

Synergistic Activities

- Developed archive for aerosol data from the AEROCE stations in the North Atlantic
- Developed algorithms for calculating dry-deposition fluxes from aerosol mass-particle size distributions
- Organized an International Conference on Mineral Dust, 1991
- Program member for the 1997 and 1998 Spring Meetings of the American Geophysical Union
- Proposal Selection Panel for several National Aeronautics and Space Administration missions

Collaborators and Other Affiliations

Collaborators. Z. S. An (State Key Lab. of Loess Quatern. Geol., PRC), J. R. Anderson (Arizona State Univ.), B. Auvermann (Texas A & M Ag Expt Stn), Y. Balkanski (Centre Nat. Recherche Scientifique, France), G. Bergametti (Univ. of Paris), J. L. Botsford, (New Mexico State Univ.), M. D. Buhr (Georgia Inst. Technol.), P. R. Buseck (Arizona State Univ.), G. Carmichael (Univ. of Iowa), G. Chen (Georgia Inst. Technol.), L. L. Chen (Univ. of Iowa), L. Q. Chen (Chinese Arctic and Antarctic Admin., PRC), T. Chen (State Key Lab. of Loess Quatern. Geol., PRC), J. H. Crawford (NASA, Langley), D. D. Davis (Georgia Inst. Technol.), J. E. Dibb (Univ. of New Hampshire), B. J. DiNunno (Georgia Inst. Technol.), W. G. Deuser (Woods Hole Oceanogr. Inst.), S. Dorling (Univ. of East Anglia, UK), R. A. Duce (Texas A & M Univ.), F. L. Eisele (NCAR), U. T. Ezat (Centre National de la Recherche Scientifique, France), J. R. Gallon (Univ. of Wales, UK), J. N. Galloway (Univ. of Virginia), Y. Gao (Rutgers Univ.), X. Gong (Georgia Inst. Technol.), L. Graninina (Limnological Institute, Russia), W. C. Graustein (Yale Univ.), D. Gu (Third Institute of Oceanogr., Xiamen, PRC), W. Guelle (Centre Nat. Recherche Scientifique, France), K. Gundersen (Univ. of Stockholm), B. G. Heikes (Univ. of Rhode Island), M. S. Hong, (Ajou Univ., Korea), S. Huang (New Mexico Tech), B. J. Huebert (Univ. of Hawaii), M. A. Izaguirre (Univ. of Miami), T. D. Jickells (Univ. of East Anglia, UK), C. Kang (Cheju Univ.) W. C. Keene (Univ. of Virginia), Y. P. Kim (Korea Inst. of Science and Technol.), T. Khodzher (Limnological Inst., Russia), A. H. Knap (Bermuda Biological Station), D. S. Lee (Yonsei Univ., Korea), H. G. Lee, (Korea Institute of Science and Technol.), B. J. Lefer (NCAR), H. Levy (Princeton Univ.), N. F. Lewis (Univ. of RI), M., F. Lipschultz (Bermuda Biological Station), S. C. Liu (Inst. of Earth Sciences, Academia Sinica, Taiwan), H. B. Maring (Univ. of Miami), B. Marticorena (Univ. of Paris), R. L. Mauldin (NCAR), C. McCormick (Univ. of Miami), J. T. Merrill (Univ. of Rhode Island), A. F. Michaels (Univ. of Southern California), J. L. Moody (Univ. of Virginia), C. Moulin (Centre Nat. Recherche Scientifique, France), K. Murano (National Inst. for Environ.l Studies, Japan), J. Nowak (Georgia Inst. Technol.), K. Orcutt (Univ of Stockholm), J. K. Park (Korea Inst. Science Tech.), T. L. Patterson (Fluor Daniels, Inc.), K. D. Perry (San Jose State Univ.), C. Pilinis (Univ. of the Aegean, Greece), J. M. Prospero (Univ. of Miami), K. A. 23Rahn (Univ. of Rhode Island), B. J. Ray (Univ. of Rhode

Island), D. L. Savoie (Univ. of Miami), M. Schulz (Univ. of Hamburg), R. Shetter (NCAR), S. Shim (Korea Inst. Science Technol.), J. A. Snow (Univ. of Rhode Island), I. N. Sokolik (Univ. of Colorado), C. H. Song (Univ. of Iowa), R. W. Talbot (Univ. of New Hampshire), D. Tanner (Georgia Inst. Technol.), U. Tomza (Univ. of Rhode Island), K. K. Turekian (Yale Univ.), H. Ueda (Kyushu Univ, Japan), M. Uematsu (Univ. of Tokyo), P. Wang (Georgia Inst. Technol.), Z. Wang (Third Inst. Oceanogr., Xiamen, PRC), G. Zhang (State Key Lab. of Loess Quatern. Geol., PRC), G. H. Zhu (State Key Lab. of Loess Quatern. Geol., PRC), X. Zhang (State Key Lab. of Loess Quatern. Geol., PRC), M. Y. Zhou (Inst. Marine Environ. Forecasting, PRC).

Graduate Advisors. MS (M. R. Tripp, retired), Ph. D. (S. Y. Feng, deceased).

Student Advisees (2). Suilou Huang (New Mexico Tech), Julie A. Snow (Univ. of Rhode Island).

Postgraduate Advisee (1). Xiao Ye Zhang (State Key Laboratory of Loess and Quaternary Geol.)

JAMES NEVILLE GALLOWAY

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EDUCATION

1966-1972 Ph.D. (Chemistry); University of California, San Diego; La Jolla, California, *Man's Alteration of the Natural Geochemical Cycles Selected Trace Metals*

1962-1966 B.A. (Biology, Chemistry); Whittier College; Whittier, California

EMPLOYMENT

1976- University of Virginia, Department of Environmental Science

1996- Chair

1988- Professor

1982-1988 Associate Professor

1976-1982 Assistant Professor

1974-1976 Postdoctoral Associate, Ecology and Systematics; Cornell University; Ithaca, New York

1972-1974 Potter; Shenandoah Crafts, Inc.; Lexington, Virginia

MOST RELEVANT PUBLICATIONS

Galloway, J. N., and J. Melillo, editors, *Asian Change in the Context of Global Climate Change*. New York: Cambridge University Press, 1999.

Galloway, J. N., The global nitrogen cycle: Changes and consequences, *Environ. Pollut.*, 102(S1), 15-24, 1998.

Galloway, J. N., Z. Dianwu V. E. Thomson, and L. H. Chang, Nitrogen mobilization in the United States of America and The People's Republic of China, *Atmos. Environ.* 30, 1551-1561, 1996.

Galloway, J. N., R. Howarth, A. Michaels, S. Nixon, and J. M. Prospero, N and P budgets of the North Atlantic Ocean and its watershed, *Biogeochemistry* 35, 3-25, 1996.

Galloway, J. N., Anthropogenic mobilization of sulfur and nitrogen: Immediate and delayed consequences, *Ann. Rev. Energy Environ.* 21, 261-292, 1996.

OTHER SIGNIFICANT PUBLICATIONS (by year)

1998 Keene, W. C., R. Sander, A. A. P. Pszenny, R. Vogt, P. J. Crutzen, and **J. N. Galloway**, Aerosol pH in the marine boundary layer: A review and model evaluation, *J. Aerosol Sci.*, 29(3), 339-356.

Russell, K. M., **J. N. Galloway**, S. A. Macko, J. L. Moody, and J. R. Scudlark, Sources of nitrogen in wet deposition to the Chesapeake Bay Region, *Atmos. Environ.*, 32(14/15), 2453-2465.

Scudlark, J. R., K. M. Russell, **J. N. Galloway**, T. M. Church, and W. C. Keene, Organic nitrogen in precipitation at the mid-Atlantic U. S. Coast - methods evaluation and preliminary measurements, *Atmos. Environ.*, 32(10), 1719-1728.

1997 **Galloway, J. N.**, Acid deposition in marine regions, in *Global Acid Deposition Assessment*, WMO/ GAW Report No. 106, edited by D. M. Whelpdale and M. S. Kaiser, pp. 177-192, WMO/ UNEP, Geneva.

Schnoor, J. L., **J. N. Galloway**, and B. Moldan, East Central Europe: An environment in transition, *Environ. Sci. Tech.*, 31(9), 412A-416A.

SYNERGISTIC ACTIVITIES

1. Developed community data base of composition of wet deposition in remote regions of the world.
2. Established a program of environmental literacy at the 24University of Virginia.

3. Will co-chair a major international conference in October 2000 on science and policy aspects of altering the nitrogen cycle.

COLLABORATORS (for the past 48 months)

Arimoto, R., New Mexico State University; Artz, R., NOAA; Ayers, G., CSIRO, Australia; Ball, W., University of Maryland; Barrett, K., Norwegian Meteorological Institute; Bulger, A. J., University of Virginia; Chang, L. H., U.S. EPA; Church, T. M., University of Delaware; Cosby, B. J., University of Virginia; Crutzen, P. J., Max Planck Institute; Currie, W. S., Ecosystems Center, Woods Hole MA; Daube, B. C., Harvard University; Delmas, R. J., Laboratory of Glaciology and Geophysics, France; Dentener, F., Utrecht University; Deviney, F. A., University of Virginia; Dianwu, Z., Academia Sinica, China; Dickerson, R. R., University of Maryland; Doddridge, B. G., University of Maryland; Dolloff, C. A., Virginia Polytechnic and State University; Dovland, H., Norwegian Institute for Air Research; Duce, R. A., Texas A & M University; Eshleman, K. N., University of Maryland; Gillett, R., CSIRO, Australia; Graustein, W., Yale University; Grennfelt, P., Swedish Environmental Research Institute; Hara, H., Institute of Public Health, Tokyo; Harris, J. M., NOAA/ERL; Hoover, D. J., University of Hawaii; Howarth, R., Cornell University; Hyer, K. E., University of Virginia; Jacob, D. J., Harvard University; Keene, W. C., University of Virginia; Lacaus, J.-P., Center of Atmospheric Research, France; Lavedas, N., University of Virginia; Levy II, H., Princeton University; Likens, G. E., Institute of Ecosystems Studies, NY; Liu, J., Yunnan Environmental Monitoring Station; Luke, W., NOAA; Maben, J. R., University of Virginia; Mackenzie, F. T., University of Hawaii; Macko, S., University of Virginia; Maring, H., University of Miami; Melillo, J., Ecosystems Center, Woods Hole MA; Merrill, J. L., University of Rhode Island; Michaels, A., University of Southern California; Mikkelsen, K., University of Virginia; Miller, J. M., World Meteorological Organization, Geneva; Milne, P. J., University of Miami; Morgan, R. P., University of Maryland; Moody, J. L., University of Virginia; Moomaw, W., Tufts University; Mosher, B. W., University of New Hampshire; Munger, J. W., Harvard University; Nixon, S., University of Rhode Island; Prospero, J. M., University of Miami; Pszenny, A. A. P., Massachusetts Institute of Technology; Quinn, P., OAA/PMEL; Russell, K. M., University of Virginia; Ryaboshapko, A., Institute of Global and Climate and Ecology, Moscow; Sander, R., Max Planck Institute; Sanhueza, E., IVIC, Caracas, Venezuela; Savoie, D. L., University of Miami; Schlesinger, W. H., Duke University; Schnoor, J. L., University of Iowa; Scudlark, J. R., University of Delaware; Shugart, H. H., University of Virginia; Southwell, M., University of Virginia; Summers, P. W., Atmospheric Environment Service, Ontario; Talbot, R. W., University of New Hampshire; Thomson, V. E., University of Virginia; Turekian, K. K., Yale University; Unruh, G., Tufts University; Vogt, R., Ford Forschungszentrum Aachen, Germany; Webb, J. R., University of Virginia; Whelpdale, D. M., Atmospheric Environment Service, Ontario

STUDENT ASSOCIATIONS

Graduate Advisees (1995-2000): Ishi Buffam, Ken Hyer, Keith Reinhardt, Kristina Russell, Deborah Todd, Vaughan Turekian, Brigitte Snyder, University of Virginia; Mary Margaret Muller Koppers, DynCorps; Kristen Krapf, RNRF, Bethesda; Amy Gianotti, (formerly) University of Virginia.

Number of graduate students and postgraduate advisees: 10

Graduate advisor: James Arnold, Chemistry Department, University of California, San Diego (retired)

Postdoc advisor: Gene E. Likens, Director, Institute of Ecosystem Studies, Millbrook, NY

WILLIAM C. KEENE

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PROFESSIONAL PREPARATION

- 1972 B.A., Department of Environmental Sciences, University of Virginia
1978 M.S., Department of Environmental Sciences, University of Virginia (Oxygen and Nutrient Dynamics in Lac de Tunis, a Hypereutrophic Subtropical Lagoon)

APPOINTMENTS

- 1977-present Department of Environmental Sciences, University of Virginia
1994-present Research Associate Professor
1990-1994 Senior Scientist
1985-1990 Research Scientist
1977-1985 Research Assistant
1980-present Manager, Environmental Chemistry Laboratories
1976-1977 Investigator, Environmental Protection Agency and Institut National Scientifique et Technique d'Océanographie et Pêche, Tunisia
1974-1976 Research Assistant, Department of Environmental Sciences, University of Virginia
1972-1973 Research Assistant, Department of Environmental Sciences, University of Virginia

FIVE MOST CLOSELY RELATED PUBLICATIONS

- Galloway, J. N., D. L. Savoie, W. C. Keene, and J. M. Prospero, The temporal and spatial variability of scavenging ratios for nss sulfate, nitrate, methanesulfonate and sodium in the atmosphere over the North Atlantic Ocean, *Atmos. Environ.*, 27A, 235-250, 1993.
Galloway, J. N., W. C. Keene, and G. E. Likens, Processes controlling the composition of precipitation at a remote southern hemispheric location: Torres del Paine National Park, Chile, *J. Geophys. Res.*, 101, 6883-6897, 1996.
Keene, W. C., B. W. Mosher, D. J. Jacob, J. W. Munger, R. W. Talbot, R. S. Artz, J. R. Maben, B. R. Daube, and J. N. Galloway, Carboxylic acids in clouds at a high-elevation forested site in central Virginia, USA, *J. Geophys. Res.*, 100, 9345-9357, 1995.
Keene, W. C., and D. L. Savoie, The pH of deliquesced sea-salt aerosol in polluted marine air, *Geophys. Res. Lett.*, 25, 2181-2194, 1998.
Moody, J. L., A. A. P. Pszenny, A. Gaudry, W. C. Keene, J. N. Galloway, and G. Polian, Precipitation composition and its variability in the southern Indian Ocean: Amsterdam Island, 1980-1987, *J. Geophys. Res.*, 96, 20,769-20,786, 1991.

FIVE OTHER SIGNIFICANT PUBLICATIONS

- Graedel, T. E., and W. C. Keene, The tropospheric budget of reactive chlorine, *Global Biogeochem. Cycles*, 9, 47-78, 1998.
Keene, W. C., M. A. K. Khalil, D. J. Erickson, A. McCulloch, T. E. Graedel, J. M. Lobert, M. L. Aucott, S.-L. Gong, D. B. Harper, G. Kleiman, P. Midgley, R. M. Moore, C. Seuzaret, W. T. Sturges, C. M. Benkovitz, V. Koropalov, L. A. Barrie, and Y.-F. Li, Composite global emissions of reactive chlorine from natural and anthropogenic sources: Reactive Chlorine Emissions Inventory, *J. Geophys. Res.*, 104, 8429-8440, 1999.
(<http://groundhog.sprl.umich.edu/geia/rcei/index.html>)
Keene, W. C., R. Sander, A. A. P. Pszenny, R. Vogt, P. J. Crutzen, and J. N. Galloway, Aerosol pH in the marine boundary layer: A review and model evaluation, *J. Aerosol Sci.*, 29, 339-356, 1998.
Lobert, J., W. C. Keene, J. A. Logan, and R. Yevich, Global chlorine emissions from biomass burning: Reactive Chlorine Emissions Inventory, *J. Geophys. Res.*, 104, 8373-8389, 1999. (<http://groundhog.sprl.umich.edu/geia/rcei/index.html>)
Pszenny, A. A. P., W. C. Keene, D. J. Jacob, S. Fan, J. R. Maben, M. P. Zetwo, M. Springer-Young, and J. N. Galloway, Evidence of inorganic chlorine gases other than hydrogen chloride in marine surface air, *Geophys. Res. Lett.*, 20, 699-702, 1993.

SYNERGISTIC ACTIVITIES

- Director, Reactive Chlorine Emissions Inventory Activity (*Journal of Geophysical Research* Special Section, see Keene et al., 1999; Lobert et al., 1999; and references therein; full citations above; <http://groundhog.sprl.umich.edu/geia/rcei/index.html>)
Algorithms developed to calculate the pHs of size-segregated aerosol solutions required to sustain the measured phase partitioning of reactive trace gases (Keene and Savoie, 1998; full citation above)
Science Committee and Session Chair, International Conference on Naturally-Produced Organohalogenes, Delft, The Netherlands, 1992-1993 (proceedings volume, 26*Naturally-Produced Organohalogenes*, Kluwer, Dordrecht,

1995).

Measurement technique developed to demonstrate existence of significant volatile inorganic chlorine other than HCl in marine surface air (Keene et al., *Environ. Sci. Technol.*, 27, 866, 1993).

Measurement techniques developed to demonstrate carboxylic acids are major, primarily natural, reactive trace constituents of the global troposphere (Keene et al., *J. Geophys. Res.*, 88, 5122, 1983; Keene and Galloway, *Tellus*, 40B, 322, 1988; and references therein).

COLLABORATORS AND OTHER AFFILIATIONS (1996-2000)

Arimoto, R., New Mexico State Univ.; Artaxo, P., Instituto del Fisica, Sao Paulo, Brazil; Artz, R. S., NOAA/ ARL; Atlas, E., NCAR; Aucott, M. L., New Jersey Dept. Environmental Protection; Bailey, R. E., Bailey Assoc.; Barrie, L. A., Atmospheric Environment Service; Benkovitz, C. M., Brookhaven National Laboratory; Church, T. M., Univ. of Delaware; Cosby, B. J., Univ. of Virginia; Crutzen, P. J., Max-Planck Inst. for Chem.; Daube, B. R., Harvard Univ.; de Leer, E. W. B., TNO Inst. Environ. Science, The Netherlands; Dickerson, R. R., Univ. of Maryland; Doddridge, B. G., Univ. of Maryland; Duce, R. A., Texas A&M Univ.; Erickson, D. J., Goddard Space Flight Center; Fan, S., Princeton Univ.; Fuentes, J. D., Univ. of Virginia; Galloway, J. N., Univ. of Virginia; Gong, S.-L., Atmos. Environ. Service, Canada; Gorzelska, K., Univ. of Mary; Graedel, T. E., Yale Univ.; Graustein, W. C., Yale Univ.; Harper, D. B., The Queen's Univ. of Belfast; Hicks, B. B., NOAA/ARL; Hosker, R., NOAA, Oak Ridge, TN; Howell, S., Univ. of Hawaii; Huebert, B., Univ. of Hawaii; Jacob, D. J., Harvard Univ.; Jayne, J. T., Aerodyne Research; Khalil, M. A. K., Portland State Univ.; Kleiman, G., Mass. Inst. Technol.; Kolb, C., Aerodyne Research; Koropalov, V., Inst. for Applied Geophys., Moscow; Lee, D. S., AEA Technology, U.K.; Li, Y.-F., Canadian Global Emissions Center; Likens, G. E., Inst. Ecosystem Studies; Liu, J., Yunnan Env. Mon. Station, Yunnan PRC; Lobert, J. M., Univ. of California, San Diego; Logan, J. A., Harvard Univ.; Maben, J. R., Univ. of Virginia; Macko, S. A., Univ. of Virginia; Maring, H., Univ. of Miami; McCulloch, A., ICI Chemicals & Polymers Ltd., U.K.; Merrill, J. T., Univ. of Rhode Island; Midgley, P., M & D Consulting, Leinfelden, Germany; Milne, P. J., Univ. of Miami; Mohnen, V., SUNY Albany; Moody, J. L., Univ. of Virginia; Moore, R. M., Dalhousie Univ.; Mosher, B. W., Univ. of New Hampshire; Munger, J. W., Harvard Univ.; O'Dowd, C., Univ. of Sunderland, U.K.; Perner, D., Max-Planck Inst. for Chemistry, Prados, A., Univ. of Maryland; Prinn, R., Mass. Inst. Technol.; Prospero, J. M., Univ. of Miami; Pszenny, A. A. P., Mass. Inst. Technol.; Rampy, L., Chem. Manufacturer's Assoc; Sander, R., Max-Planck Inst. for Chemistry; Savoie, D. L., Univ. of Miami; Scudlark, J. R., Univ. of Delaware; Seuzaret, C., NCAR; Sokolik, I., Univ. of Colorado; Sturges, W. T., Univ. of East Anglia; Talbot, R. W., Univ. of New Hampshire; Turekian, K. K., Yale Univ.; Vogt, R., Ford Forschungszentrum, Aachen, Germany; Winterton, N., Univ. of Liverpool, U.K.; Worsnop, D., Aerodyne Research; Yevich, R., Harvard Univ.

STUDENT ASSOCIATIONS

Student Advisees (1996-2000): W. Dockery III, K. M. Russell, Deborah Todd, Vaughan C. Turekian
University of Virginia

Number of graduate students and postgraduate advisees: 3

Graduate advisor: Mahlon Kelly, University of Virginia (retired)

Irina N. Sokolik
Associate Professor
Program in Atmospheric and Oceanic Sciences
University of Colorado at Boulder
Campus Box 311
Boulder, CO 80309
Telephone: (303) 234-5503
e-mail: sokolik@lasp.colorado.edu
<http://irina.colorado.edu>

Professional Preparation

- 1984 M.S. (Atmospheric physics), Moscow Institute of Physics and Technology;
1989 Candidate of Science (Ph.D. Equivalent), (Atmospheric Physics), Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow.

Appointments

- 2000-present Associate Professor with tenure, Program in Atmospheric and Oceanic Sciences, University of Colorado University at Boulder
1997-2000 Research Associate, PAOS, University of Colorado at Boulder
1996-1997 Research Scientist, Bay Area Environmental Research Institute, NASA/Ames Research Center, Moffett Field, CA
1993-1996 Research Associate, National Research Council, NASA/Ames Research Center, Moffett Field, CA
1992-1993 Research Associate, CIRES, University of Colorado at Boulder
1991-1992 Visiting Fellow, CIRES, University of Colorado at Boulder
1993 Senior Scientist, Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow
1989-1992 Research Scientist, Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow
1984-1989 Junior Research Scientist, Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow

Five Most Closely Related Publications

- Pirogov S.M., Romashova E.V., and I.N. Sokolik. Measurements of optical and radiative characteristics of dust aerosol. In: "Joint Soviet-American experiment on arid aerosol: Tadzhikistan, USSR, September 1989", Ed. Golitsyn G.S., pp. 21-26, 1992.
Sokolik I.N., O.B. Toon, and R.W. Bergstrom. Modeling the radiative characteristics of airborne mineral aerosols at infrared wavelengths. J. Geophys. Res. 103, 8813-8826, 1998.
Sokolik I.N. and O.B. Toon. Incorporation of mineralogical composition into models of the radiative properties of mineral aerosol from UV to IR wavelengths. J. Geophys. Res., 104, 9423-9444, 1999.
Sokolik I.N. Nuts and bolts of radiative forcing by mineral dust. IGACtivities Newsletter, Issue 17, 12-14, May 1999.
Sokolik I.N. Challenges add up in quantifying radiative impact of mineral dust. Eos, 48, 1999.

Five Other Significant Publications

- Sokolik, I.N., Interpretation of the measurements of optical characteristics of smoke aerosol. Izvestiya Acad.Sci., Atmos. and Oceanic Physics 24, 200-204, 1988.
Sokolik I.N. Microphysical, optical and radiative properties of Arctic aerosols. Izvestiya Acad. Sci., Atmos. and Oceanic Physics, 7, 675-688, 1992.
Sokolik I.N. and Golitsyn G.S. Investigation of optical and radiative properties of atmospheric dust aerosols. Atmos. Environment. 16, 2509-2517, 1993.
Sokolik I.N., F.P.J. Valero, and P. Pilewskie. Spatial and temporal variations of the radiative characteristics of the plume from the Kuwait oil fires. In "Biomass burning and global climate change", Levine

J.S., Ed., MIT Press: Cambridge, MA, pp. 889-893, 1996.

Sokolik I.N. and O.B. Toon. Direct radiative forcing by anthropogenic airborne mineral aerosols. *Nature* 381, 681- 683, 1996.

Synergistic Activities

Participated in experimental planning, acquisition and analysis of data during several international field missions such as Joint Russian-American Experiment on Arid Dust (1989-1991); AGASP-IV (Arctic Gas and Aerosol Sampling Program), 1991-1992; SCAR-C (Smoke, Clouds, and Radiation – California) international field experiment, 1994.

Organized and Chaired the Workshop on Mineral Dust, June 9-11, 1999, Boulder (about 100 participants from 9 countries; see <http://irina.colorado.edu/workshop.htm>)

Organized a special issue on Mineral Dust in *Journal of Geophysical Research- Atmosphere* (about 57 papers, expected publication date 12/2000).

Developed and teach course ATOC3500 “Air Chemistry and Pollution”. Full lecture notes are available from the web site: <http://irina.colorado.edu/teaching.htm>. This course was selected as a basis for an IGAC-Education online course.

Collaborators and Other Affiliations

Collaborators: R. Arimoto (Carlsbad Environmental Monitoring & Research Center); G. Bergametti (Paris University 7); R. Bergstrom (BAER Institute); G. Carmichael (Iowa University); D. Gillette (NOAA); E. Dutton (NOAA); G. Golitsyn (Russian Academy of Sciences); L. Gomes (Paris University 7); W. v. Hoyningen-Huene (University of Bremen); B. Huebert (Univ. of Hawaii), Y. Kaufman (NASA); B. Keene (University of Virginia); Y.P. Kim (Korea Institute of Science and Technology); J. Ogren (NOAA/CMDL); J. Penner (University of Michigan); P. Pilewskie (NASA/Ames); J. Prospero (University of Miami); O.B. Toon (University of Colorado at Boulder); M. Uematsu (University of Tokyo); F.P. Valero (University of California), D. Winker (NASA)

Graduate Advisors: M.S. (Prof. Karasev, retired); Ph.D. (Prof. G. Golitsyn, Russian Academy of Sciences)

Graduate Student Advises: Ana Lia Quijano, Olga Kalashnikova, Renee Tatusko (all University of Colorado at Boulder)

FACILITIES, EQUIPMENT & OTHER RESOURCES: Arimoto, New Mexico State Univ.

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. Use additional pages if necessary.

Laboratory: Two laboratories at the Carlsbad Environmental Monitoring & Research Center, New Mexico State University, each 526 ft² are dedicated for use in environmental chemistry studies. The laboratories are equipped with an analytical balance, pH meter, several clean benches (one with an acid scrubbing filter), water baths, hot plates, a rotating extractor, and other standard laboratory instrumentation in addition to three 8-ft fume hoods. Ultra-pure deionized (18.2 MΩ) water is prepared with a Barnstead Nanopure® water purification system.

Clinical: N/A

Animal: N/A

Computer: Three networked microcomputers are available for use in the environmental chemistry laboratories. The PI and each of the other personnel involved in this proposal have dedicated microcomputers networked to the center's computer system with internet and email access. CEMRC has acquired 'Sample Master' from Accelerated Technology Laboratories as the sample-tracking module of the Center's Laboratory Information Management System.

Office: Collating photocopiers, numerous printers, a bed plotter, a facsimile machine and other standard office equipment are available.

Other N/A

:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate, identify the location and pertinent capabilities of each.

The environmental chemistry (EC) laboratories house a Dionex 500 ion chromatography system (2 separate columns, pumps, etc), a Perkin-Elmer 5100 atomic absorption spectrometer (with flame, graphite furnace, and flow injection), and a Perkin-Elmer Elan 6000, inductively-coupled plasma-mass spectrometer. Two microwave digestion units (a Milestone Ethos and a CEM MDS2100) are available for sample preparation. A Mettler UMT2 microbalance, a Mettler MT5 microbalance, and a Sartorius Analytical balance with a weighing pan designed for aerosol filters are available for use in a laboratory across the hall from the EC laboratories. A comprehensive set of analytical instrumentation is available for radiochemical analyses. The CEMRC field team uses and maintains a wide variety of sampling equipment, including two fully instrumented meteorological stations; low-volume, high-volume, size-selective, dichotomous, and multiple orifice inlet aerosol samplers; soil and sediment collection devices; ground water and surface water collection equipment; *in situ* water quality instrumentation; and an *in situ* NaI gamma radiation detection system.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual/subaward arrangements with other organizations.

A machine shop, electronics shop, and a glassblower are available at NMSU, Las Cruces



FACILITIES, EQUIPMENT & OTHER RESOURCES: Keene, Univ. of Virginia

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. Use additional pages if necessary.

Laboratory: The Environmental Chemistry Laboratories in the Department of Environmental Sciences are modern and well equipped. These facilities include 2 general analytical laboratories, a clean laboratory (positive pressure, absolute air filtration, and laminar flow hoods), and a dedication room for acid washing. Standard laboratory equipment includes: pH meters, strip chart recorders, conductivity bridges, analytical balances, refrigerators, freezers, fume hoods, centrifuges, sonicators, a vacuum oven, and a muffle furnace.

Clinical: N/A

Animal: N/A

Computer: Data are retrieved from analytical instruments, reduced, compiled, QA'ed, and archived on 3 laboratory computers. In addition, the PI has both a desk-top and a lap-top computer that are employed for interpreting and reporting results. The lab-top computer will be used during Science Team meetings and site visits to facilitate data entry and transfer.

Office: The PI, the laboratory technician, and the program support technician have dedicated offices to support their respective components of the project.

Other N/A

:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate, identify the location and pertinent capabilities of each.

Major analytical instruments that will be used for this project include: 2 Dionex Model 4000 gradient elution ion chromatographs with automated sample injectors, and conductivity detectors; a Dionex AI450 Data Acquisition System with 2 advanced computer interfaces, a dual-beam Thermo Jarrell Ash model Smith-Hieftze 22 atomic absorption/atomic emission spectrophotometer; a dual channel Technicon Autoanalyzer II; two 24"x48" class 100 clean benches, and a Barnstead deionizing system.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual/subaward arrangements with other organizations.

The department supports a well-equipped machine shop and full-time machinist for the fabrication of specialized equipment and replacement of failed components.



FACILITIES, EQUIPMENT & OTHER RESOURCES: Sokolik, Univ. of Colorado

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. Use additional pages if necessary.

Laboratory: The University of Colorado at Boulder has many modern well-equipped laboratories, which are available to the PI if required. In particular, a new aerosol optics and radiation (AOR) laboratory headed by the PI will be used. This laboratory will house a workshop on instrument's intercomparison and calibration proposed under this project.

Clinical: N/A

Animal: N/A

Computer: University of Colorado at Boulder has excellent modern computer facilities. In addition, the JOSS/NCAR computer facilities will be used for data archival. The PI has both a desktop personal computer and a laptop computer that will be employed for this project.

Office: The PI and students have dedicated offices, modern personal computers, access to a copy machine, scanner, and other standard office equipments.

Other N/A

:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate, identify the location and pertinent capabilities of each.

Major instruments that will be used for this project are spectral aethalometer, spectral integrating nephelometer, open-air integrating nephelometer, sun/sky radiometers, automatic solar tracker, pyranometers, and pyrgeometers.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual/subaward arrangements with other organizations.

The department supports a well-equipped machine shop and full-time machinist for the fabrication of specialized equipment and replacement of failed components.



I. SPECIAL INFORMATION/SUPPLEMENTARY DOCUMENTATION

E-Mail messages of support from each of the Regional Coordinators are attached below

Date: Fri, 07 Jan 2000 01:27:43 +0800
From: "Prof. Neng-Huei (George) Lin" <nhlin@rainbow.atm.ncu.edu.tw>
X-Mailer: Mozilla 4.08 [en] (Win98; I)
To: Rich Arimoto <arimoto@cemrc.org>
Subject: Re: Letter of support

Dear Rich,

In response to your e-mail dated on 1/5/2000, I certainly support your plans for co-ordinating the ACE-Asia Network Operations. In particular, the development of standard operating procedures and measures for quality assurance and quality control is extremely important for carrying out a successful field experiment. I have no objection for your proposal.

Please let me know, if further assistance is needed from the science team of Taiwan.

Best regards,

George

--

Neng-Huei (George) Lin, Ph.D.
Professor
Department of Atmospheric Sciences
/Department of Chemistry
National Central University
Chung-Li, TAIWAN
Tel&Fax: +886-3-4254069
E-mail: nhlin@rainbow.atm.ncu.edu.tw
<http://aerosol.atm.ncu.edu.tw>

X-Mailer: Macintosh Eudora Pro Version 4.0.1J
Date: Sat, 8 Jan 2000 12:59:06 +0900
To: Rich Arimoto <arimoto@cemrc.org>
From: mitsuo uematsu <uematsu@ori.u-tokyo.ac.jp>
Subject: Letter of support
Cc: wck@virginia.edu, sokolik@lasp.colorado.edu,
kawamura@soya.lowtem.hokudai.ac.jp

Dear Rich,

As the regional site co-ordinator in Japan, I strongly would like to support your plans for co-ordinating the ACE-Asia Network Operations which you are going to submit a proposal to NSF.

We, among Japanese groups who are studying the ACE-Asia related field observations, are trying to exchange the information and to have the common consensus in our country. We need the strong co-ordination among the countries who are planning to join the activity of the ACE-Asia Network as early as possible. There will be many difficulties to co-ordinate the network beyond the countries. However, our effort will be rewarded by the great scientific success in East Asia where is the most important region facing to the global environmental change.

with best regards,
Mits

=====
Mitsuo Uematsu
Center for International Cooperation
Ocean Research Institute
University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo 164-8639 Japan
voice & FAX:+81-3-5351-6533
=====

Date: Sat, 08 Jan 2000 15:19:09 +0900
From: Sungnam Oh <snoh@metri.re.kr>
X-Mailer: Mozilla 4.6 [en] (Win98; I)
X-Accept-Language: en
To: Rich Arimoto <arimoto@cemrc.org>
Subject: Re: Letter of support

Dear Dr. Rich Arimoto:

Thank you for your e-mail informing that you are preparing a coordinated proposal. I think it is necessary to accomplish the goal of ACE-Asia. I am very grateful for your effort to organize ground network study. I understand how much difficult and time-consuming job it is, based on my experience working on Kosan site. I hope that your proposal get funded from NSF and I will do my best for successful operation of Kosan site.

Best wishes for you and your work,

Sungnam Oh
Ph.D.
Director of Applied Meteorology Research Lab.
Meteorological Research Institute
phone: +8242-846-2850
Fax: +8242-846-2851

=====

Date: Mon, 10 Jan 2000 16:21:28 +0800
From: "zrj@mail.iap.ac.cn" <zrj@mail.iap.ac.cn>
Reply-To: zrj@mail.iap.ac.cn
Organization: zrj@mail.iap.ac.cn
X-Mailer: Mozilla 3.01Gold (Win95; I)
To: arimoto@cemrc.org
Subject: Re: ACE-project

Dear prof. Arimoto:

Prior to the 1980s, Chinese scientists have noted the potential environmental and climatic importance of aerosols as a result of more and more severe "acid rain", "air pollution", "global climate change", and increasing sandstorm events. A series of experiments and theoretical analyses in aerosol investigation have been carried out. A great amount of data and some analyzed results have been obtained, some of which have been submitted to several international conferences. As the development of economy in Asia regions, aerosols in Asia play more and more important role in climate and environment in regional and even global scale. In China, Scientists from various institutes or department have taken part in the ACE research program. Many scientists from USA, Japan, Korea, Hongkong etc.al also joined in ACE project. So I am very pleased that you USA scientists are apply the project to coordinate some of the ACE-Asia network activities. That is an important and great plan. We Chinese side will do our best to support your project.

Sincerely yours,

Renjian Zhang

Institute of Atmospheric Physics
Chinese Academy of Sciences
Beijing 100029
Tel: 86-10-62359642
Fax: 86-10-62028604

X-Sender: cetwang@polyu.edu.hk
X-Mailer: Windows Eudora Version 1.4.4
To: Rich Arimoto <arimoto@cemrc.org>
From: cetwang@polyu.edu.hk (Dr. Wang Tao)
Subject: Re: Letter of support
Date: Wed, 12 Jan 2000 09:34:48 +0800

Here is the email letter of support. -Tao

Dear Dr. Arimoto,

This is to indicate my support of your plan to coordinate the ACE-Asia network activities. The proposed task, such as identification of representative sites, intercomparison of instrumentation, and establishment of a network-wide quality assurance and control program, will be an crucial part of the overall efforts in obtaining a high-quality chemical data set across the entire network. I will do my best to collaborate with you and your colleagues in implementing this important undertaking.

Please do not hesitate to contact me should you need any specific assistance in the above efforts.

Sincerely yours,

Tao Wang, Ph.D.
Project Scientist, the HKPU Air Monitoring Project
ACE-Asia Regional Site Coordinator (Hong Kong)
Tel: (852)2766-6059
Fax: (852)2334-6389
Email: cetwang@polyu.edu.hk

Letters from Galloway and Sievering